A FIELD GUIDE TO MUSKEG SPILL RESPONSE

Prepared by:

PRAIRIE REGIONAL OIL SPILL CONTAINMENT AND RECOVERY ADVISORY COMMITTEE
RESEARCH AND DEVELOPMENT SUBCOMMITTEE

for

CANADIAN PETROLEUM ASSOCIATION

FEBRUARY 1987

CANADIAN PETROLEUM ASSOCIATION

A FIELD GUIDE TO MUSKEG SPILL RESPONSE

PREPARED BY:

PRAIRIE REGIONAL OIL SPILL CONTAINMENT AND
RECOVERY ADVISORY COMMITTEE
RESEARCH AND DEVELOPMENT SUBCOMMITTEE

for

CANADIAN PETROLEUM ASSOCIATION

FEBRUARY 1987

90-043987

A FIELD GUIDE TO MUSKEG SPILL RESPONSE

TABLE OF CONTENTS

		Page
PREFACE		i
LIST OF TABLES		ii
LIST OF FIGURES		iii
1.	RESPONSE STRATEGIES	1
1.1	Objective	1
1.2	Response Options	1
1.3	General Approaches	10
1.3.1	Physical Containment and Recovery	10
1.3.2	Delayed Cleanup	10
1.3.3	Burning	10
1.3.4	Natural Processes	11
2.	SPILL SITE ASSESSMENT	12
2.1	Wetlands or Muskeg Types	12
2.1.1	Bogs	12
2.1.2	Fens	12
2.1.3	Marshes	12
2.2	Safety Precautions	12
2.3	Action Plan	13
2.3.1	Initial Action	13
2.3.2	Field Assessment for Oil Spills	13
2.3.3	Field Assessment for Salt Water Spills	14
2.4	Spill Boundaries	16
2.5	Sampling	17
2.6	Documentation	19
2.6.1	Purpose of Keeping Records	19
2.6.2	Procedures for Documenting the Spill	19
2.6.2.1	The Spill Report	20
2.6.2.2	Sketch of the Spill Site	20
2.6.2.3	Photographs	22
2.6.2.4	Initial Recovery	23
2.6.2.5	Sample Results	23
2.6.2.6	Reclamation Plan	23

TABLE OF CONTENTS (Continued)

		Page
3.	OIL SPILL CONTAINMENT	25
3.1	Introduction	25
3.2	Trenches and Bell Holes	26
3.3	Dikes	28
3.3.1	Earth Dikes	28
3.3.2	Straw Dikes	31
3.3.3	Snow Dike	32
3.4	Containment Weirs	33
3.4.1	Inverted Culverts	33
3.4.2	Straight Culverts	35
3.4.3	Planks	37
3.5	Containment	39
3.6	Filter Fences	41
3.7	Culvert Blocks	43
3.8	Ice Slotting	45
4.	OIL SPILL RECOVERY	46
4.1	Overview	46
4.2	Flushing	46
4.3	Fluid Recovery	48
5.	OIL SPILL CLEANUP	52
5.1	Stripping	52
5.2	Burning	53
5.3	Manual Removal	55
5.4	Disposal of Oily Debris	56
6.	SALT WATER SPILL CONTAINMENT	61
6.1	Introduction	61
6.2	Containment Techniques	62
6.2.1	Dikes	62
6.2.2	Trenches and Bell Holes	63
7.	SALT WATER SPILL RECOVERY	66
7.1	Recovery Techniques	66
7.1.1	Bell Holes	66
7.1.2	Flushing and Pumping	68

TABLE OF CONTENTS (Concluded)

		Page
8.	SALT WATER SPILL CLEANUP	71
8.1	Temporary Storage	71
8.2	Transportation	71
8.3	Disposal	72
9.	RECLAMATION	73
9.1	Planning	73
9.2	Site Considerations	73

PREFACE

The "Field Guide to Muskeg Spill Response" was developed by a subcommittee of the Research & Development Committee of The Prairie Regional Oil Spill Containment and Recovery Advisory Committee (PROSCARAC). The subcommittee was composed of environmental representatives from various oil companies in Western Canada and government regulatory representatives. These individuals brought to the project many years of muskeg spill response experience and knowledge. This knowledge was combined with information from existing publications and condensed into a field manual for muskeg spill response.

This manual is intended to assist field personnel in determining appropriate strategies for spill containment, recovery and disposal. Each spill is unique and the techniques described in the manual are not applicable to every situation.

LIST OF TABLES

		Page
1(a).	Response Strategies - Oil Spills in Muskeg: SUMMER	3
1(b).	Response Strategies - Oil Spills in Muskeg: WINTER	4, 5
2(a).	Response Strategies - Salt Water Spills in Muskeg: SUMMER	6
2(b).	Response Strategies - Salt Water Spills in Muskeg: WINTER	7
3.	Advantages and Disadvantages of Recovery Equipment	50, 51
4.	Storage of Oil Spill Debris	57
5.	Disposal of Oil Spill Debris	58, 59 60

LIST OF FIGURES

		Page
1.	Response Strategies: Oil Salt Water Spills	2
2.	Typical Bog	8
3.	Typical Fen	8
4.	Typical Marsh	9
5.	Spill Site Assessment	15
6.	Standpipes for Sampling Muskeg	18
7.	Sample Bailer	18
8.	Typical Trench/Bell Hole	26
9.	Earthen Dike	29
10.	Snow Dike	32
11.	Inverted Culvert	34
12.	Straight Weir (Plank)	36
13.	Containment Booms	40
14.	Filter Fence	42
15.	Subsurface Filter Fence	42
16.	Culvert Blocks	44
17.	Oil Herding on Open Water	47
18.	Cone of Depression Around Bell Hole	67

FIELD GUIDE TO MUSKEG SPILL RESPONSE

1. RESPONSE STRATEGIES

1.1 OBJECTIVE

The objective in selecting a response strategy following a spill, is to select the most effective actions to minimize environmental impact without compromising safety and economic considerations.

Experience shows a substantial reduction in reclamation time and costs are possible if proper response strategies are selected and implemented for all stages of spill response - containment, recovery and cleanup.

1.2 RESPONSE OPTIONS

Figure 1 illustrates how response strategies are decided. Table 1 summarizes the key issues and the containment and recovery methods for oil spills in muskeg in summer and winter. Table 2 provides the same information applied to salt water spills.

Following the initial response (stopping the leak and on-site assessment), the next step is to choose a response strategy for containment and recovery. Information gained from the on-site assessment plays a key role in decision-making.

FIGURE 1

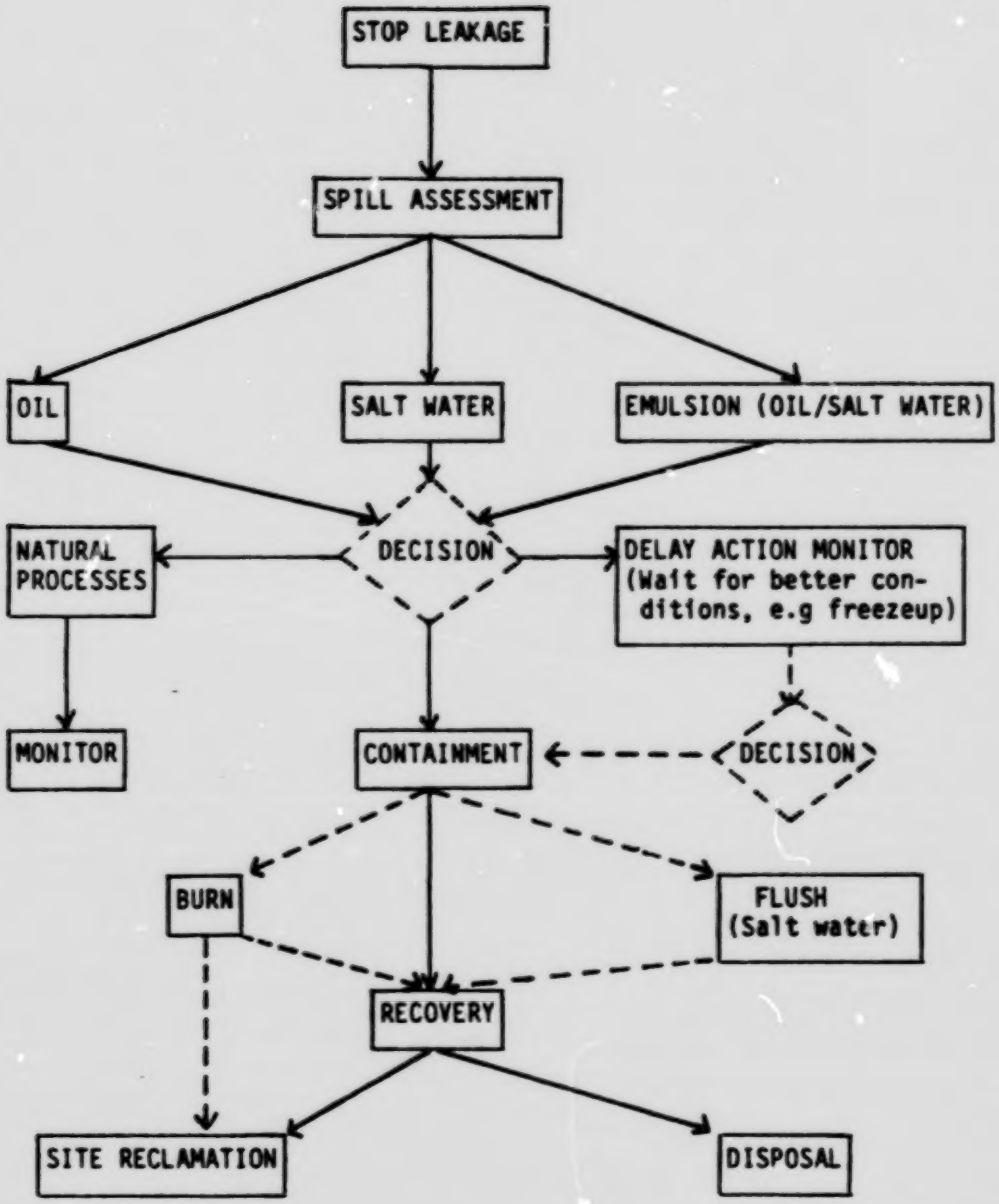

FIGURE 1. RESPONSE STRATEGIES: Oil and Salt Water Spills In Muskeg

TABLE 1(a). RESPONSE STRATEGIES - Oil Spills in Muskeg: SUMMER

Muskeg Type	Key Issues	Containment	Recovery
Typical Bog			
o small trees, shrubs and grasses o semi solid waste o no open water o water table below surface	o oil pooled and likely to migrate	o dike (straw or dirt) o trenches	o pumps/vacuum trucks o trenches & bell holes o flush (warm water)
	o oil pooled and stationary	o trenches and bellholes	o pumps/vacuum trucks o flush (warm water)
	o oil saturated into peat	o trenches and bellholes	o pumps/vacuum trucks o flush (warm water) o windrow saturated peat
Typical Fen			
o shrubs, grasses, no trees	o oil likely to migrate - direction of water flow	o booms o dikes/invert culverts o filter fences	o pumps & skimmers o flush (warm water) o sorbent
o some open water o water table at or near surface	o oil pooled and stationary	o shallow trenches & bellholes o dikes (straw/sorbant)	o pumps & skimmers o vacuum trucks o flush (warm water) o burning possible with controls after initial recovery completed
	o Aquatic habitat and wildlife protection	o if possible boom oil away from nesting areas and beaver houses, etc.	o avoid burning
Typical Marsh			
o wetland, grass or no vegetation at all o mostly open water with vegetation at sides o no firm base	o aquatic habitat/wildlife protection	o contain away from habit and nesting areas if possible	o no burning on recovery
	o direction of water flow -oil likely to migrate	o booms o filter fences o dikes/invert culvert	o skimmers/pump o sorbent pads and rolls o burning possible with controls after initial recovery completed
	o oil pooled on surface - stationary	o booms o filter fences o dikes/straw and sorbant	o skimmers & pumps o sorbent pads or rolls o burning possible with controls after initial recovery completed

TABLE I(b). RESPONSE STRATEGIES - Oil Spills in Muskeg: WINTER

Muskeg Type	Key Issues	Containment	Recovery
Typical Bog			
o small trees, shrubs and grass o frozen with firm base to support equipment o water table below surface	o oil pooled and likely to migrate	o dike (straw, snow, dirt) o shallow trenches and bellholes	o vacuum trucks o scrape & remove o flush (warm water) o burning possible after initial recovery completed
	o oil pooled and stationary	o shallow trenches and bellholes	o vacuum trucks o scrape & remove o flush (warm water) o burning possible after initial recovery completed
	o oil saturated into peat	o shallow trenches and bellholes	o vacuum trucks o scrape & remove o flush (warm water) o burning possible after initial recovery completed
	o oil trapped below frost layer in voids	o bellholes o rip below frost layer to expose oil	o vacuum trucks

* Check for explosive gases under snow cover before proceeding work.

TABLE 1(b) continued. RESPONSE STRATEGIES - Oil Spills in Muskeg: WINTER

Muskeg Type	Key Issues	Containment	Recovery
Typical Fen			
o shurbs, grasses, no trees o some open water (frozen) o fairly solid base o water table at or near surface	o oil pooled on surface and migrating	o dikes (snow, straw, dirt) o shallow trenches and beliholes	o vacuum trucks o scraping o flush (warm water) o burning possible after initial recovery complete
	o oil on surface and stationary	o shallow trenches	o vacuum trucks o skimmers/pumps o scraping
	o oil under ice and stationary	o slot or trench through ice	o vacuum trucks o skimmers/pumps
Typical Marsh			
o mostly water (frozen) o vegetation at edges	o aquatic habitat and wildlife	o isolate from pushups and beaver houses	o no burning on recovery
	o oil below ice and migrating	o slot ice for recovery	o skimmers & pumps o sorbent
	o oil on surface and migrating or stationary	o slot ice for recovery	o burning when initial recovery complete o skimmers & pumps o sorbent
		o dikes (snow, straw, dirt)	o vacuum trucks o scraping o flushing (warm water) o burning with initial recovery complete

* Check for explosive gases under snow cover before proceeding work.

TABLE 2(a) RESPONSE STRATEGIES - Salt Water Spills in Muskeg: SUMMER

Muskeg Type	Key Issues	Containment	Recovery
Typical Bog			
o small trees, shrubs and grasses o semi-solid base o no open water o water table below surface	o depth of salt water penetration o direction of water flow (water table) o extent of migration and damage to vegetation	o trenches (lined if possible) o bellholes o dikes	o pumps o vacuum and/or water trucks o flush (cold water)
Typical Fen			
o shrubs, grasses, no trees o some open water o water table at or near surface	o direction of water flow (water table) o extent of migration o aquatic habitat	o dikes (dirt) o trenches	o pumps o vacuum and/or water trucks o flush (cold water)
Typical Marsh			
o wetland grasses or no vegetation at all o mostly open water with vegetation at edges o no firm base	o direction of water flow o extent of contamination in fresh water o high concentration - spill on bottom of marsh o aquatic habitat protection	o dike (dirt) if possible downstream of leak	o pumps o vacuum and/or trucks o flush (cold water)

TABLE 2(b) RESPONSE STRATEGIES - Salt Water Spills in Muskeg: WINTER

Muskeg Type	Key Issues	Containment	Recovery
Typical Bog			
o small trees, shrubs and grasses o frozen with firm base to support equipment	o depth of salt water penetration o direction of water flow (water table)	o trenches (lined if possible) o bellholes o dikes	o pumps o vacuum and/or water trucks o scrape up and remove salt water/slush o flush (cold water)
Typical Fen			
o shrubs, grasses, no trees o some open water (frozen) o fairly solid frozen base	o direction of water flow (water table) o extent of migration	o shallow trenches (lined if possible) o shallow bellholes o dikes (dirt)	o pumps o vacuum and/or water trucks o scrape up and remove salt water/slush o flush (cold water)
Typical Marsh			
o mostly water frozen o vegetation at edges	o aquatic habitat o direction of water flow o extent of migration o spill under ice; high concentration on bottom of marsh.	o dikes (dirt) downstream of leak	o pumps o vacuum and/or water trucks o flush (cold water)

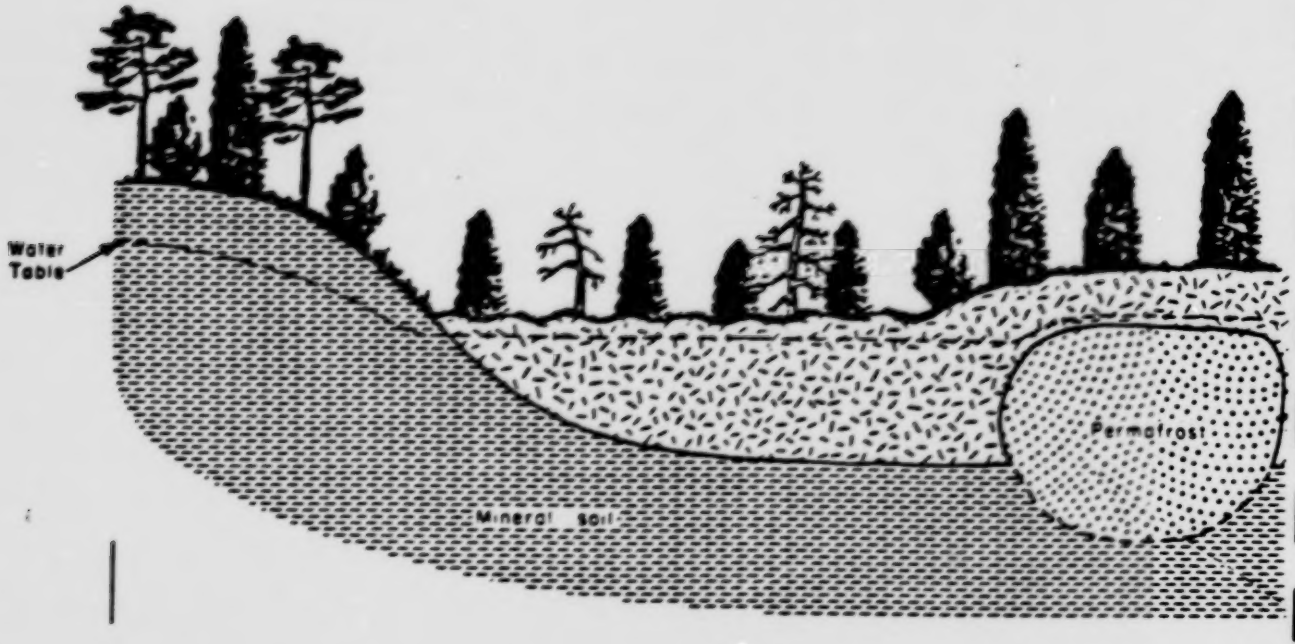

FIGURE 2 TYPICAL BOG

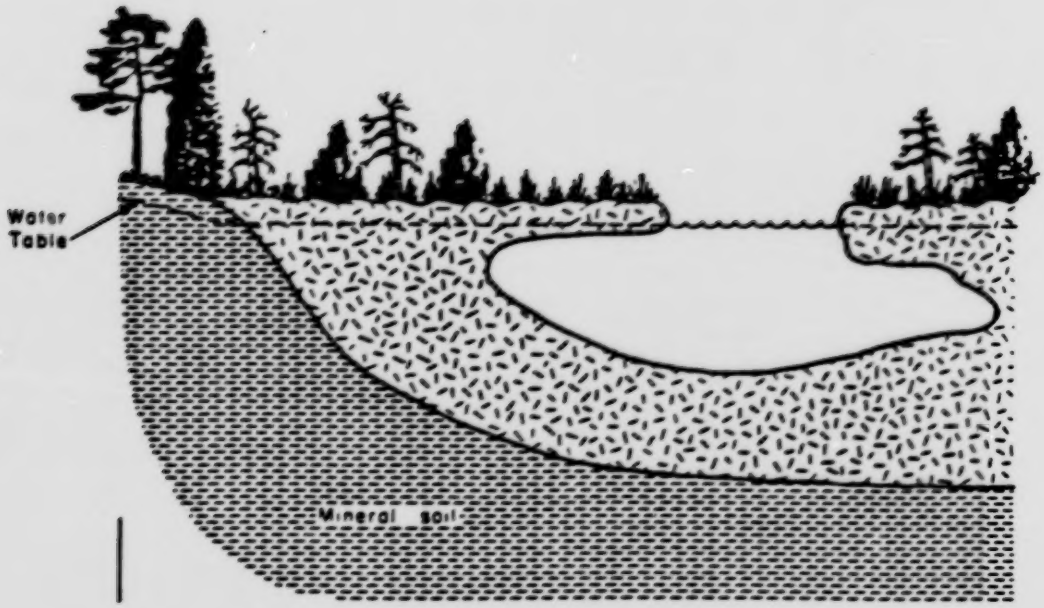

FIGURE 3 TYPICAL FEN

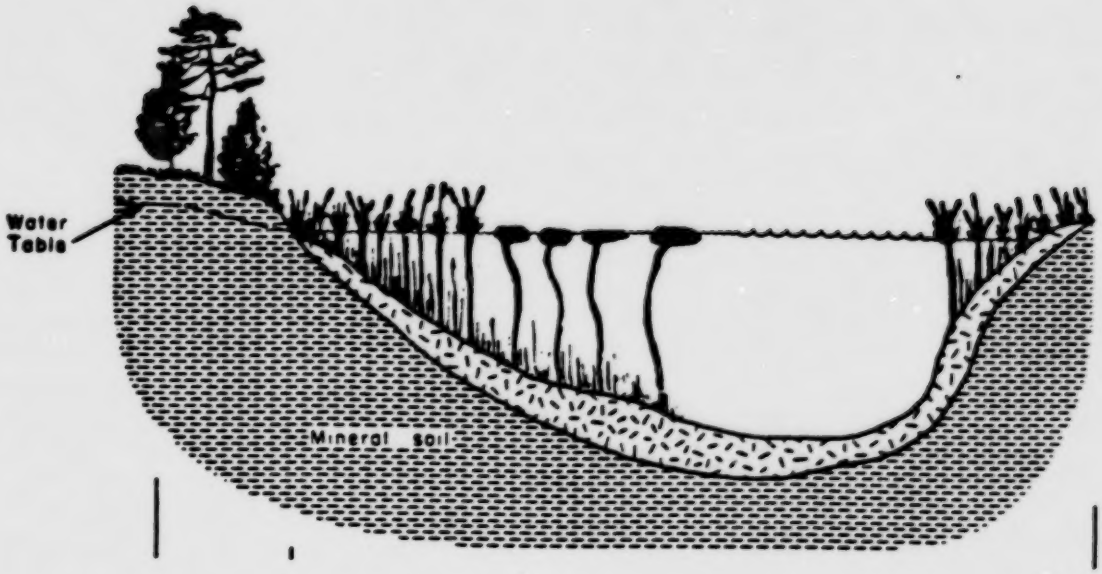

FIGURE 4 TYPICAL MARSH

1.3 GENERAL APPROACHES

1.3.1 Physical Containment and Recovery

If the situation is safe (lack of explosive gases, etc.) and site conditions suitable, containment and recovery actions should be taken. Some examples are:

- o Trenching
- o Bell holes
- o Dikes
- o Flushing
- o Fluid recovery

1.3.2 Delayed Cleanup

If site conditions are too soft, or safety considerations, such as the presence of explosive gases, prevent immediate containment and recovery actions, work may have to be delayed until freeze up or until safety conditions are acceptable. Delaying action may require some changes to the final cleanup strategy. The site must be monitored until cleanup begins. All parties affected; Company, Government agencies and landowners, should agree with the decision to delay cleanup and on the degree of monitoring required until cleanup can be resumed.

1.3.3 Burning

Burning can be a viable first response strategy under certain conditions though it is generally considered an option of last resort. Burning can effectively remove safety concerns about

the presence of explosive gases or can be used to mitigate spill impact on wet muskeg where ground conditions prevent access and mechanical equipment would cause serious terrain damage. The advantages and disadvantages of burning are detailed in Section 5.3. These factors should be carefully weighed to determine if burning is the appropriate response.

1.3.4 Natural Processes

The parties involved with the spill may decide that more environmental damage to the site would result from cleanup operations than from the spill itself. This would usually only be acceptable for small spills.

Site monitoring is required to ensure the spill is not spreading and assess the natural reclamation rate. Minor work, such as fertilizing, may be desirable to accelerate natural site reclamation processes.

2. SPILL SITE ASSESSMENT

2.1 WETLAND OR MUSKEG TYPES

Determine the type of muskeg that is involved, its drainage patterns, and location of surface water in the area.

Muskeg is a poorly drained, wet, spongy area ranging from open water to sparsely treed. Key points in regard to spill assessment are:

- o there is usually slow internal drainage.
- o depth of peat over mineral soil is extremely variable.
- o they are acidic and low in nutrients.

2.2 SAFETY PRECAUTIONS

Human safety is the prime consideration in spill cleanup activities. The following safety precautions must be respected:

- o Immediately determine whether there is a fire and explosion hazard. Use extreme caution where oil is under the snow or organic layer.
- o Identify whether H_2S is present and use care in low lying areas.

- Remember that people and equipment are slower moving in muskeg than on firmer surfaces and that escape routes are usually limited.

2.3 ACTION PLAN

2.3.1 Initial Action

The initial steps in assessing the spill site are:

- Identify the spilled material and its potential safety hazards.
- Identify the spill source and stop further leakage, if this can be done safely.
- Identify the exact spill location, access to the site, creeks, rivers and ponds in the area.
- Stop spilled material from migrating into surface water, if possible.

2.3.2 Field Assessment for Oil Spills

The term "oil spill" can refer to spilled condensate as well as light or heavy crude oil. Spills often contain bulk hydrocarbons (oil) and salt water.

Some things to remember are:

- There may be a risk of fire.
- In some cases H_2S may be present.
- Except for some heavy crude oil, hydrocarbons float on water and do not readily mix in water.
- Oil spills are usually highly visible. However, if the spilled product is beneath a floating muskeg or snow it may be difficult to see.

2.3.3 Field Assessment for Salt Water Spills

Salt water may be spilled by itself or may be found in a part of an oil spill. When dealing with a salt water spill there are several things to keep in mind:

- Salt water is heavier than fresh water and mixes with water.
- Salt water is non-volatile, but may contain H_2S.
- Salt water at 1 700 ppm can have a detrimental effect on fish.
- The effects of a salt water spill may not be apparent until vegetation becomes stressed or dies.

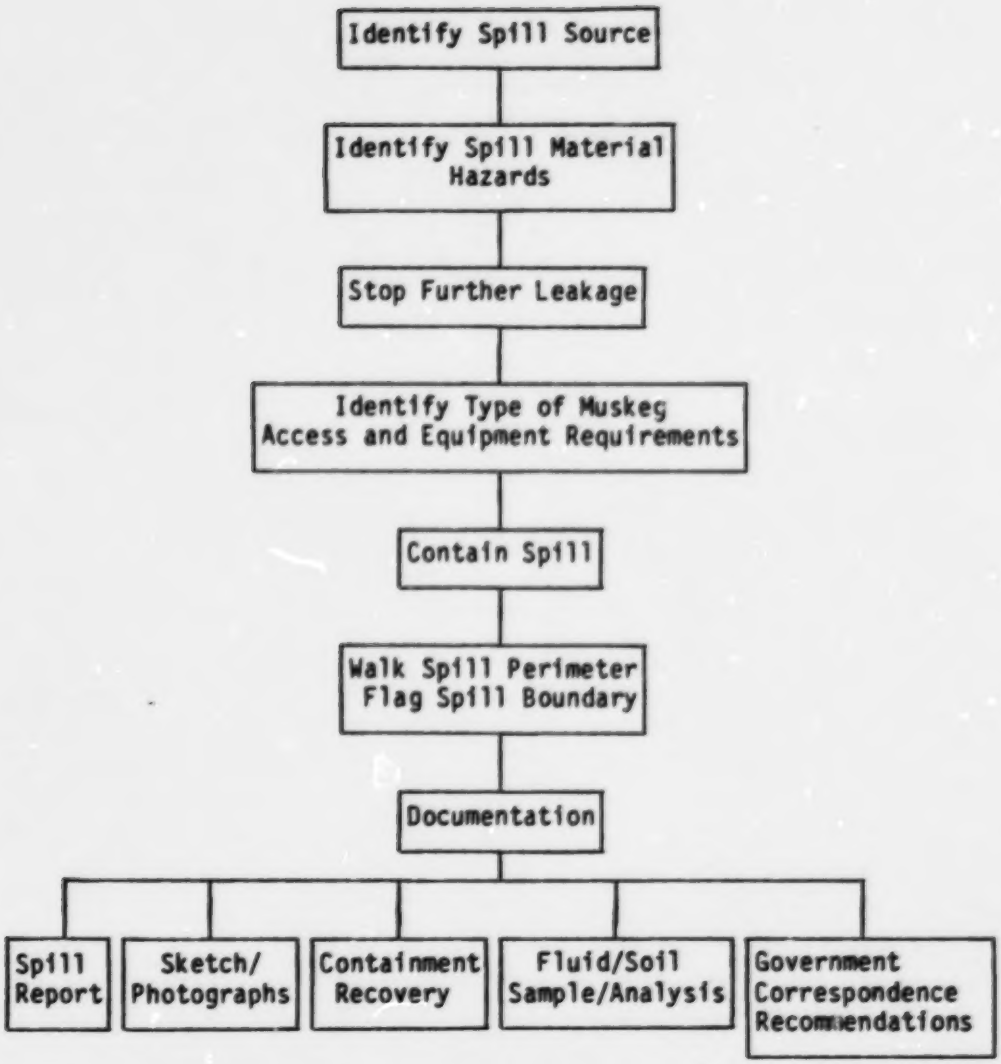

FIGURE 5. SPILL SITE ASSESSMENT

2.4 SPILL BOUNDARIES

At the earliest opportunity the perimeter of the spill should be marked with flagging. This helps in choosing containment sites and in monitoring the spread of the spill.

The following equipment may be required when determining and marking the spill boundary:

- helicopter or fixed-wing aircraft for aerial assessment.
- plastic snowshoes (if the ground is not frozen).
- compass and surveyor's tape or range finder.
- a shovel.
- a chloride titrator kit for salt water spills. The kit includes titrators, empty film containers, notebook and pen.
- flagging tape and lathes for marking the perimeter.
- explosive meter, if condensate or other volatile product is spilled.
- H_2S monitor, if the presence of sour gas is suspected.

2.5 SAMPLING

The purpose of intial sampling is to track the movement and severity of the pollutant for containment and recovery purposes.

Samples can be collected from surface waters in trenches, bell holes, natural depressions or by excavating small sampling holes.

For subsurface migration it may be necessary to install stand pipes in a series radiating out from the spill source as shown in Figure 6. Samples can be collected from stand pipes with a simple fabricated bailer. An example is shown in Figure 7.

At each sampling location several pipe sections are inserted at different depths to determine pollutant movement.

For salt water spills a field analysis can be conducted to determine chloride concentration. This can be done with titration kits, an electroconductivity meter or approximated by quantabs.

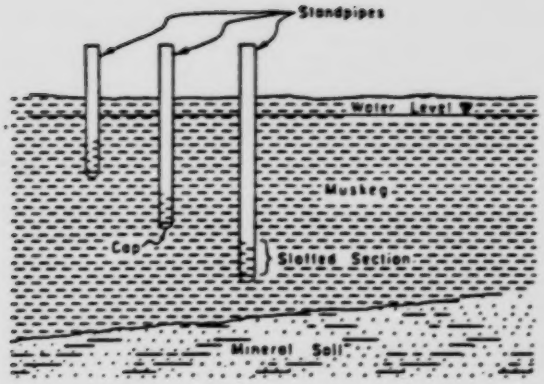

FIGURE 6

Stand pipes - fabricated from 5 cm I.D. PVC or ABS pipe with 15 cm slotted section to allow water entry.

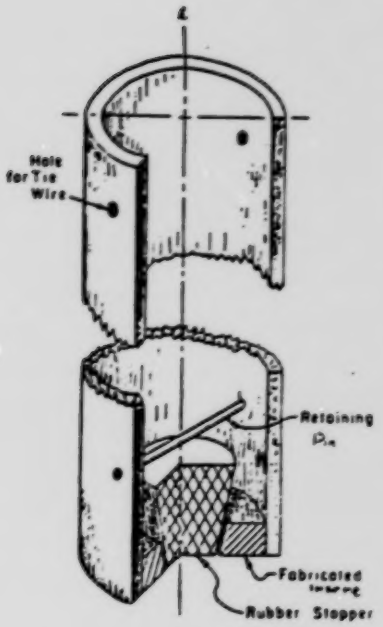

FIGURE 7

Bailer - fabricated from 3.8 cm I.D. PVC or ABS with rubber stopper valve.

2.6 DOCUMENTATION

2.6.1 Purpose of Keeping Records

During a spill cleanup and reclamation program it is important to keep good records. This documentation is necessary for:

- o Assessing the extent of on-site damage.
- o Recording agreements and future dealings with landowners, government agencies and insurance companies.
- o Determining the effectiveness of the cleanup and providing information for reclamation activities.
- o Compiling information for dealing with future spills and possible training purposes.

2.6.2 Procedures for Documenting the Spill

The procedures for properly documenting a spill site are:

The personnel responsible for documenting the spill must be familiar with company and government requirements for spill reporting and documentation.

The steps necessary in documenting a spill are based on common sense. The following sections provide guidance on what to

include. Proper documentation consists of relevant information that will aid in:

- o Outlining the area involved.
- o Determining the extent of damage and the most economic method of restoration.
- o Recording the restoration work done and an evaluation of the effectiveness.

2.6.2.1 The Spill Report

Complete the spill report. The spill report form used by individual companies and government agencies contain the basic information (date, location, volume, spill type, etc.) necessary to begin the documentation.

It is also necessary to obtain a sample of the spilled product and have it analyzed for salinity. The analysis will determine the pH of the spilled product (whether spill is acidic or basic) and the level of salts present.

This information will assist in determining the effect of the spill on the land and will aid in future reclamation planning.

2.6.2.2 Sketch of Spill Site

Prepare a sketch of the spill sites and document the area affected by the spill. Indicate the locations of convenient

reference points, soil samples and the direction of both surface and sub-surface drainage.

A sketch of the spill area should include:

- North arrow
- Spill boundaries (essential in later dealings with government or landowner)
- Dimensions of the spill (to be indicated along the spill's boundaries)
- Location of the break or source of spill
- Permanent reference points (power poles, buildings, creeks, etc.) and estimated distances from the spill
- Water bodies (creeks, sloughs, etc.) affected by or adjacent to spill area
- Locations of dike or interceptor trenches
- Sample locations
- Types of adjacent vegetation. In farmland, indicate crop type. In forested land, indicate the type of tree cover, e.g., poplar, spruce or bog, etc.

2.6.2.3 Photographs

Take photographs of the spill area to show site conditions at the time of the spill and to document the extent and area of the spill. Photographs also help with:

- o Reclamation planning
- o Reports to government
- o Determining reclamation effectiveness

Ensure that there are sufficient photographs to show entire spill area. Whenever possible include permanent reference points in the photo. This can be used later to locate the same area.

- o On the backs of the photos indicate:
- o The name and location of the spill
- o The date
- o The direction in which the photo was taken
- o Other important remarks

Whenever possible, take photos of the area adjacent to the soil sample areas. Utilize additional photos to highlight soil sample locations, potential problem areas and areas that were only lightly affected.

2.6.2.4 Initial Recovery

Document the initial recovery of the spilled product to note the recovery methods used and the results. This can be done by noting type of recovery used (flushing and vacuum trucks, trenching, burning, windrowing, etc.) This information can be very important in reclamation planning. Keep a record of the amount of product recovered and the amount left on the site.

2.6.2.6 Sample Results

Keep a record of the type and location of soil samples and of the analytical results. The information will reduce future soil sampling costs by avoiding repletion. It may be required later for submission to government.

Ensure that the following are kept in the spill file:

- o sketch showing soil sample locations
- o analysis results for soil samples and laboratory comments (if applicable)

2.6.2.6 Reclamation Plan

Reclamation plans and government correspondence illustrate what was recommended for the site and the explanations for the recommendations. As well, they document government's approval of the reclamation techniques.

To record this information, include all recommendations from Environmental Department staff, consultants or government agencies. Also, indicate which recommendations were followed, which were not and the reasons why.

3. OIL SPILL CONTAINMENT

3.1 INTRODUCTION

After the source of the spill has been shut-off and the initial site assessment completed, the next step is to contain the spill product.

Containment operations must be undertaken immediately to:

- o Stop further oil migration.
- o Reduce the amount of containment equipment required.
- o Minimize recovery and cleanup costs.

There are several containment methods which can be used to stop or reduce oil migration. These are described in the following sections. In many cases, one method is used in concert with one or more other methods. The methods used depends on spill conditions and equipment availability.

The ability and ingenuity of individuals to adapt these methods to each spill situation is the key to the success of the cleanup operation.

3.2 TRENCHES AND BELL HOLES

(a) Application

Trenches and bell holes can be excavated around the spill perimeter to prevent further oil migration. Trenches should be kept narrow and shallow to prevent unnecessary site disturbance.

In porous soils which are permeable, plastic liners or sorbant blankets should be used to reduce oil seepage into the ground. In these cases, it would be advantageous to construct a back-up trench or bell hole to monitor sub-surface movement of oil in the soil or with the ground water.

Trenches are adaptable to most sites, even in frozen conditions. Feeder trenches can be tied into the containment trench to promote fluid movement to a recovery point and aid the flushing procedure.

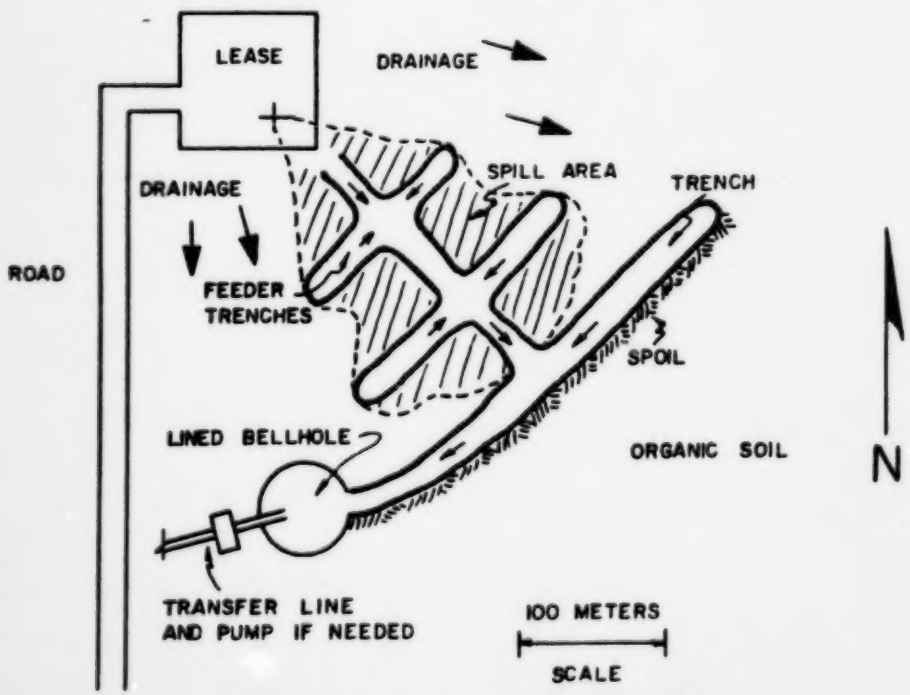

FIGURE 8 TYPICAL TRENCH/BELL HOLE

In muskeg with a high water table, a water surface is created in the trench or bell hole allowing for recovery of oil with skimming devices.

(b) Limitations

It is not uncommon in muskeg areas for trenches or bell holes to fill with water as they are excavated. When this happens oil inflow to the collection points is not likely to occur. To overcome this problem the trench bottoms must be sloped to direct fluid to the recovery point. In order to maintain flow toward the trenches, pumps or skimmers should continously remove water and oil. This type of operation requires careful planning and regular maintenance.

On sloping ground, inflow of surface run-off can cause severe erosion of trench bottom. This can be a major problem with siltation of surface water and result in site restoration problems at a later date.

(c) Advantages

- Trenches can be readily constructed with all types of equipment including hand tools.
- Trenches can direct oil to central collection points (bell holes).
- Trenches can assist in drying out the spill area to facilitate reclamation.

- o A network of collection trenches and bell holes used in combination with flushing can be very effective in cleanup operations.

- o Feeder trenches can be excavated and adapted to suit the needs of most spill areas.

(d) Disadvantages

- o In muskeg terrain, construction opportunities may be limited because of soft terrain. Also, the possibility of extensive terrain damage caused by equipment movements must be considered.

- o Road construction may be necessary to make the site accessible for equipment.

3.3 DIKES

3.3.1 Earth Dike

(a) Application

One of the most common methods of containment involves construction of a dike in conjunction with trenching around the perimeter of the spill. However, muskegs do not always have suitable soil materials on hand to construct an earth dike. Soil materials must then be hauled in from another location.

An impervious earth dike combined with an outflow control device, such as a weir, can be very effective in raising or maintaining water levels in a muskeg to reduce contact between the oil and vegetation/organic matter. Raising the water level can help float oil to the surface and assist with recovery.

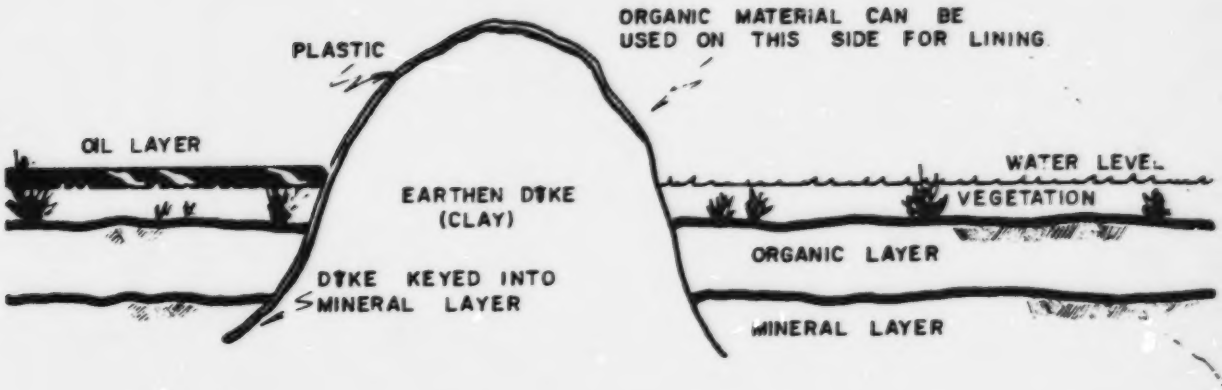

FIGURE 9 EARTHEN DIKE

(b) Limitations

Dikes should not be used in situations where the oil is beneath a vegetation layer. The dike may cause the water table to rise, moving the oil up into the surface vegetation where further containment occurs. The oil may also move outward, affecting a wider area.

In some muskeg spill areas, if the water supply is limited or the area is large, it may be difficult to raise the water table.

Earth dikes are also expensive because the source of construction is generally remote and access road construction is required to deliver the material. Also, when spill containment and recovery is completed, the dike will need to be removed, another costly operation.

(c) Advantages

- Dikes provide an adequate means for retaining both light and heavy oils as well as water.
- The top of the dike provides access and a working surface from which to deploy recovery equipment.

(d) Disadvantages

- Organic layers in muskeg are often thick requiring a substantial amount of impervious material to construct the dike.
- The source of earth fill construction material may be some distance from the site so transportation costs would be high.
- Heavy equipment is required for dike construction which requires access to the site and likely to result in excessive surface disturbance.
- Dikes need to be removed after cleanup is complete to restore the water table to normal levels.
- Construction and use is limited to small sites.

3.3.2 Straw Dike

(a) Application

On sites where suitable soil materials are not present and a barrier is required to contain oil, the dike could be constructed of straw or hay bales. Straw bales are not very effective in containing water but in combination with a shallow trench and a sorbant or plastic covering, they can be effective in containing oil.

(b) Limitations

- Limited for use on small spills.
- Should only be used for short term containment.

(c) Advantages

- Dikes can be easily constructed with hand labour.
- Bales, if not excessively contaminated after use, can be disposed of on site.

(d) Disadvantages

- The life of the dike is limited - about two months in summer.
- The dike can be costly, especially in remote areas where the straw bales must be imported from a distant location.

3.3.3 Snow Dike

(a) Application

Dikes constructed of compacted snow and ice can be placed around a spill area in winter to prevent oil migration. A snow dike can be effectively reinforced with a light application of water which is allowed to freeze.

Snow dikes function best on ice surfaces where a seal can be made between ice cover and the dike.

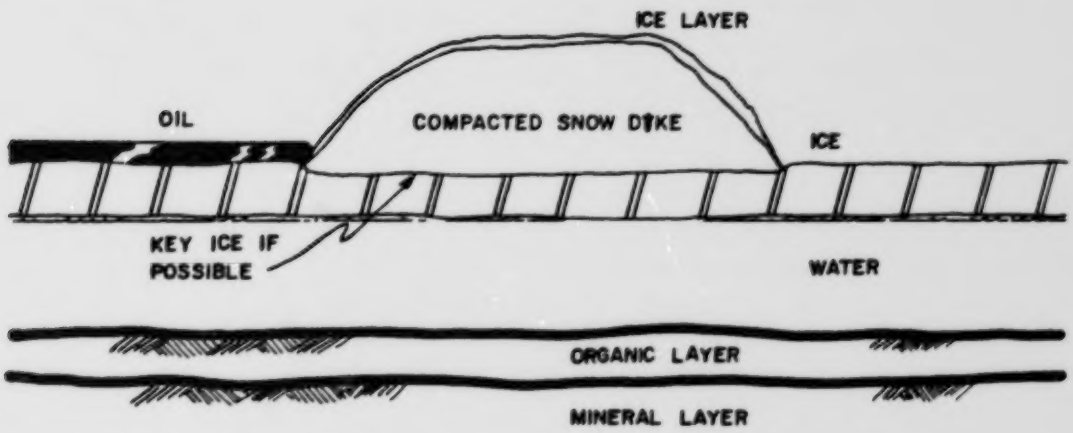

FIGURE 10 SNOW DIKE

(b) Limitations

This method is limited to muskeg with no water movement on surface. Snow dikes may cause water levels to rise, making it difficult to work on the site and can mix oil into the ice layers.

(c) Advantages

- o There is no need to import earthfill for construction.
- o Simple to construct.
- o Remove themselves in the spring.

(d) Disadvantages

- o May be difficult to construct with certain snow conditions and lack of water.
- o May be ineffective with highly permeable products (condensate).

3.4 CONTAINMENT WEIRS

3.4.1 Inverted Culverts

(a) Application

Inverted culverts set in dams or dikes can be used to control and allow for water movement while containing surface oil. As well, they can be used to maintain a constant water level within the spill site and assist with recovery.

A weir constructed using the inverted culvert technique is shown in Figure 11.

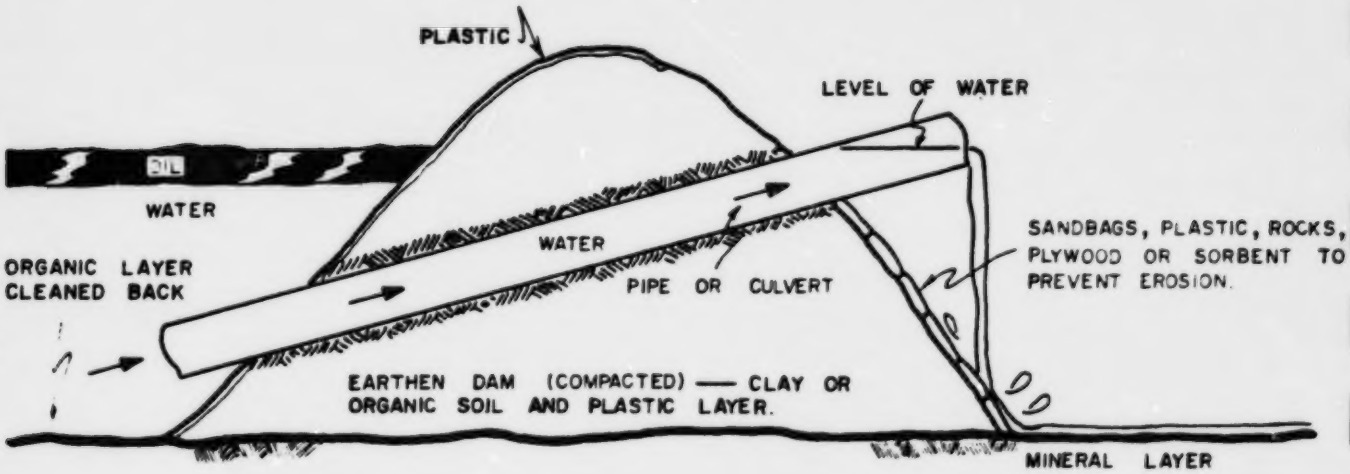

FIGURE 11 INVERTED CULVERT

(b) Limitations

Improper culvert sizing can cause problems with containment during high water flow and cause dam or dike to wash out.

(c) Advantages

- o Inverted culverts can be added to existing containment dikes.

- o Water level can be easily adjusted by moving culvert outfall up or down.

- o The oil is contained while the water is continuously released.

(d) Disadvantages

- o Earthfill material is not always present in muskeg to construct a containment weir.

- o Special care is required to compact soil or other material around the pipe to prevent leakage.

- o The downstream or outfall side of culvert requires protection to prevent the dam from washing away.

3.4.2 Straight Culverts

(a) Application

Straight culverts set in a dam or dike can be used in muskeg areas to contain subsurface oil (heavy oil) without affecting the natural movement of water through an area. They can also be used to maintain a constant level of water within the spill area.

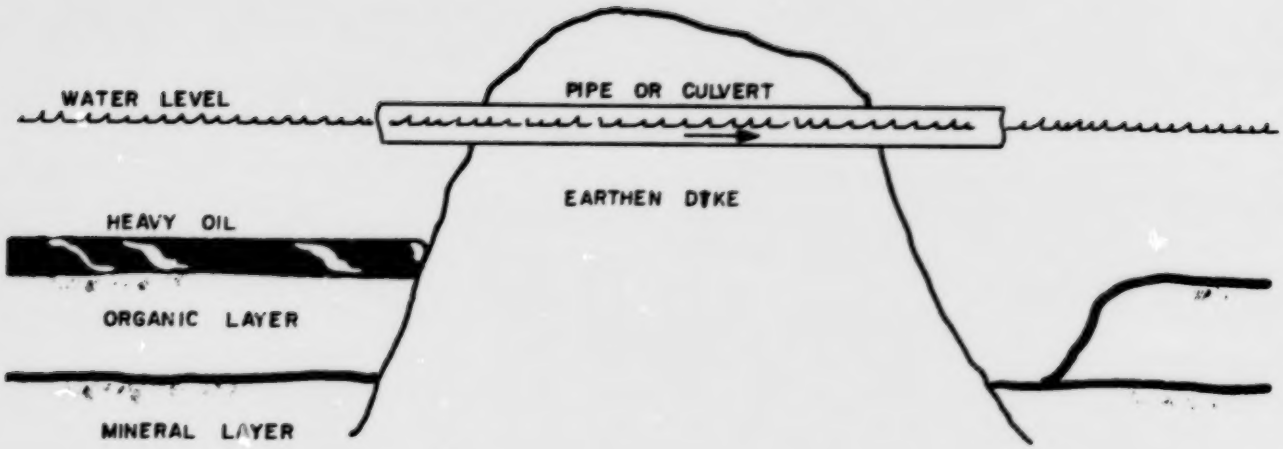

FIGURE 12 STRAIGHT WEIR (PIPE)

(b) Limitations

Culvert sizing is critical to allow for adequate movement of water. If too small, may result in flooding or washout of the dam or dike.

(c) Advantages

- o Can be added to existing containment dikes.
- o Water is released while the oil on the bottom is contained.

(d) Disadvantages

- o Special care is required to compact soil or other material around culvert to prevent leakage.
- o Earthfill material is not always present in muskeg to construct a containment weir.
- o The downstream or outfall side of culvert requires erosion protection to prevent the dam from washing away.

3.4.3 Planks

(a) Application

Planks can be used in conjunction with dams or dikes as a weir to contain oil on the water surface while allowing for movement of water under the plank.

This is shown in Figure 12.

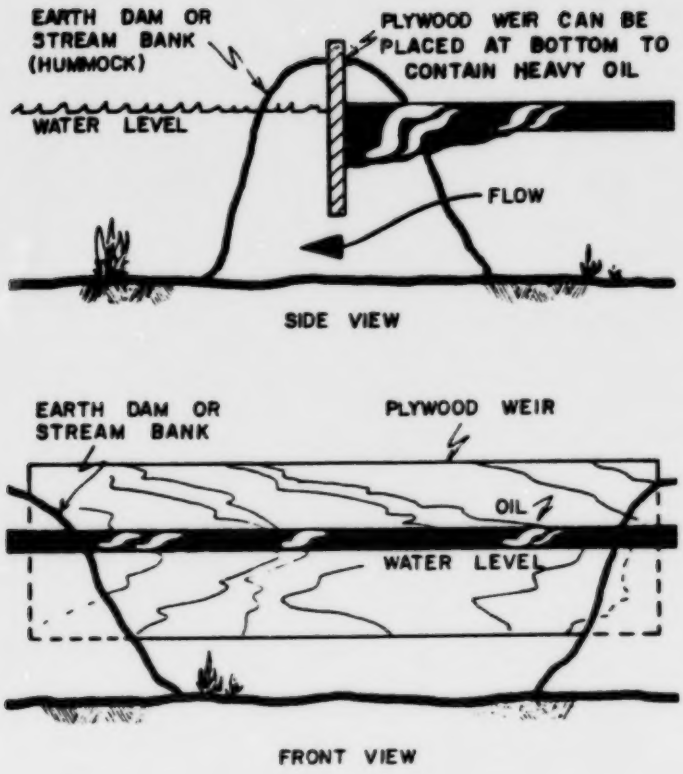

FIGURE 12 STRAIGHT WEIR (PLANKS)

(b) Limitations

This procedure is not effective on a large scale or in fast moving water.

(c) Advantages

- o Can be placed between two small dikes or naturally occuring hummocks.
- o System can be contructed with limited use of heavy equipment and, in most cases, manually.
- o Can be easily removed and moved to other locations as needed.

- They are simple to remove after cleanup.

(d) Disadvantages

- Use is best suited to ice free conditions.
- Not effective in fast flowing water or on large scale spills.

3.5 CONTAINMENT BOOMS

(a) Application

In spill situations (marshes) where there is sufficient water depth (15-20 cm), containment booms can be used to prevent oil migration without significantly affecting water movement. They can also be used to herd oil to the recovery areas by sweeping oil slowly along the water surface. This procedure can be very effective in keeping oil from spreading over aquatic vegetation and away from bird nesting and feeding areas.

Figure 13 shows the principles of oil containment using a boom.

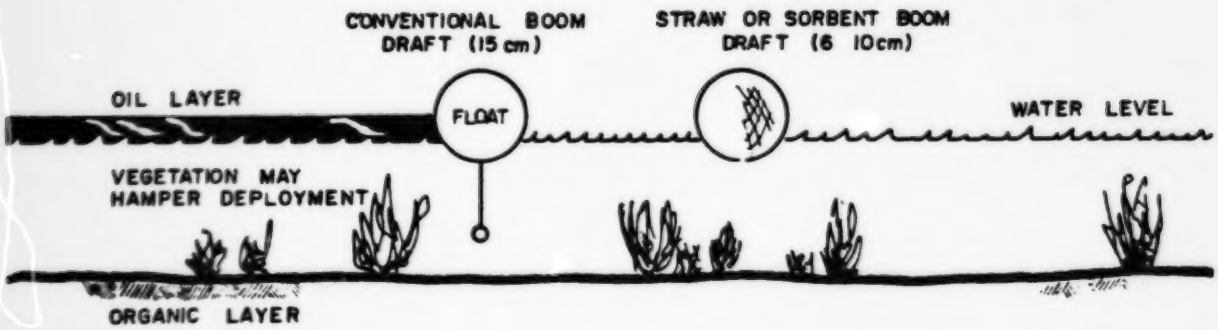

FIGURE 13 CONTAINMENT BOOMS

(b) Limitations

Deployment and movement of booms can be hampered by vegetation protruding up through the water. Booms can only be used effectively in open water muskegs.

(c) Advantages

- Booms are readily available from the oil spill Co-ops or Oscar Units.
- Booms can be constructed on-site using natural or synthetic materials (eg. straw, spruce boughs, logs, sorbant blankets, etc.).

- o These barriers are lightweight and can be handled and deployed manually. Environmental damage is minimal.

- o They can be easily moved from one area to another.

(d) Disadvantages

- o Floatation is hampered by surface vegetation.

- o Use of booms restricted to open water, ice free conditions and in water with a depth greater than draft of boom.

- o Only contains surface oil.

3.6 FILTER FENCES

(a) Application

Filter fences may be used in moving or flowing water within muskeg areas to contain surface or subsurface oil without severely affecting the natural water movement. They can also help remove oil sheens from water surface when used in conjunction with sorbants.

The construction of filter fences is shown in Figures 14 and 15.

(b) Limitations

Because of construction techniques, this method is restricted to shallow water.

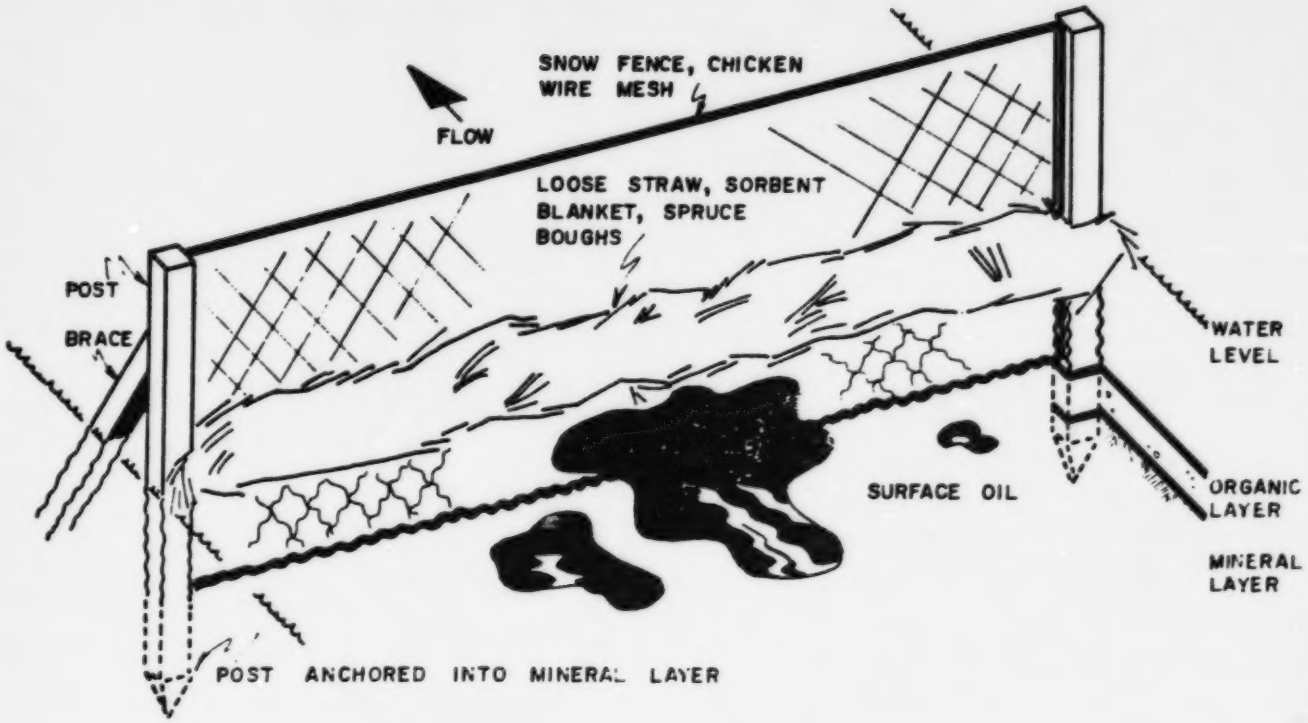

FIGURE 14 FILTER FENCE

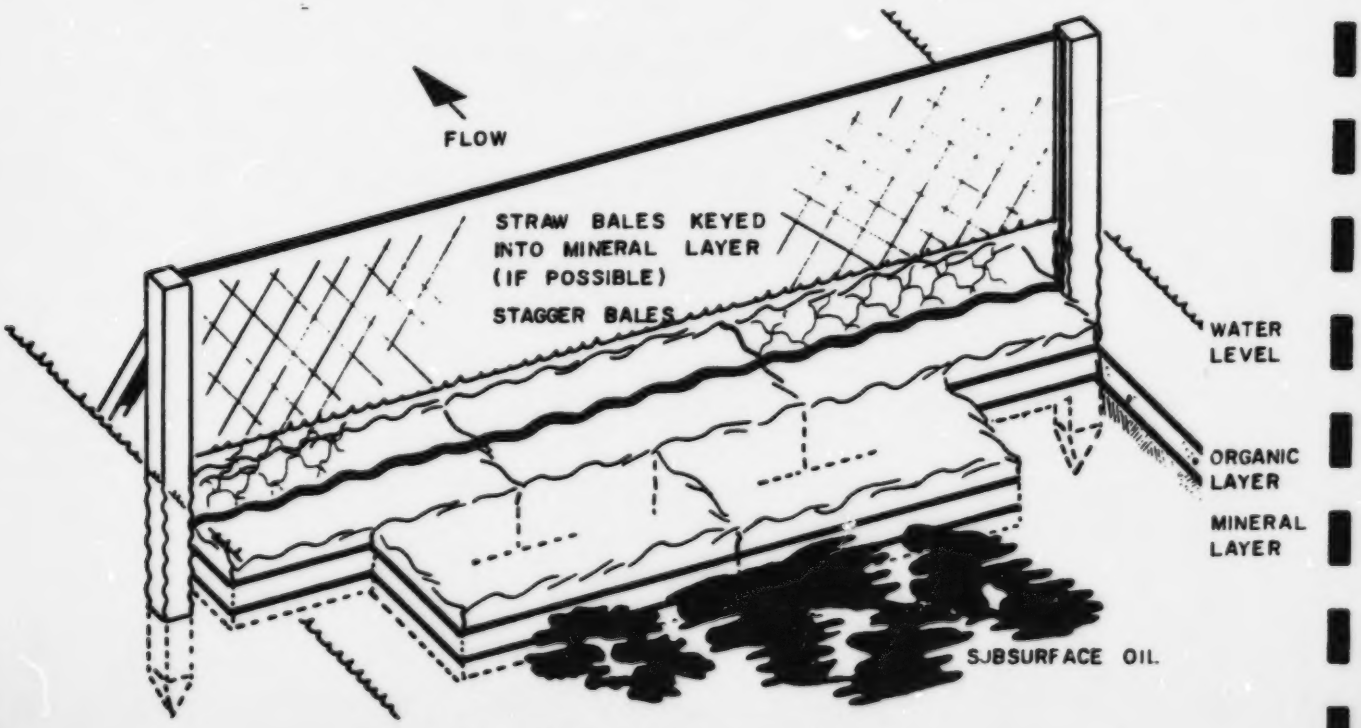

FIGURE 15 SUBSURFACE FILTER FENCE

(c) Advantages

- o Filter fences will contain surface and subsurface oil layers while allowing for water to pass through.
- o All materials for construction are light and can be handled manually.
- o Sorbents, such as straw, are usually readily available.
- o Construction is simple.
- o Removal or relocation is easy.

(d) Disadvantages

- o Limited to use in shallow water.
- o Difficult to anchor if organic soil is deep.
- o Sorbent material requires changing regularly.

3.7 CULVERT BLOCKS

(a) Application

Barriers can be placed in front of or in culverts to restrict or prevent the flow of water or oil. Barriers should be adjustable so they can be altered as spill conditions change. Blocks can be simple blow up bladders inserted inside the culvert.

Some techniques to block a culvert are shown in Figure 16.

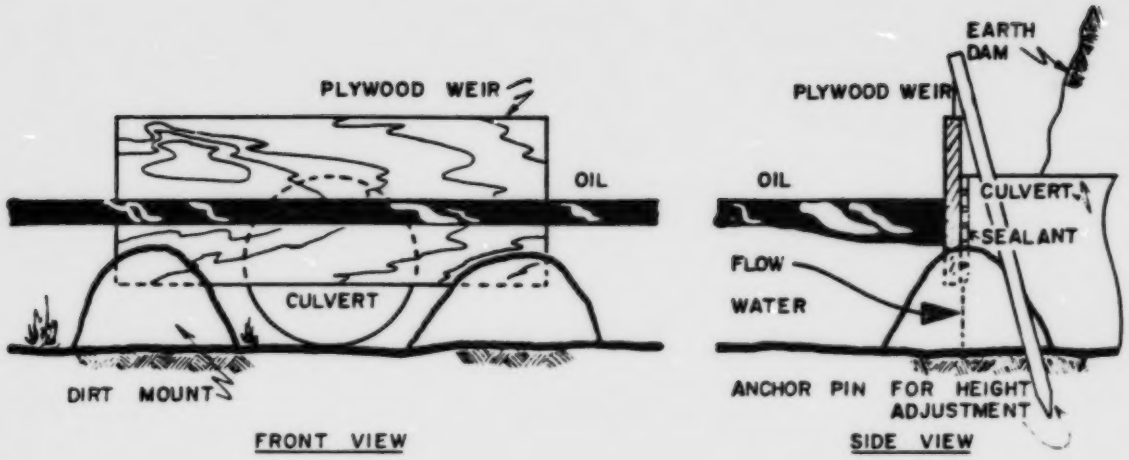

FIGURE 16 CULVERT BLOCKS

(b) Limitations

Adjustment of the culvert block to raise or lower the weir height may be difficult.

(c) Advantages

- o The barrier can be adjusted to prevent or permit water movement and to retain oil.
- o Requires simple construction techniques.
- o Fast to implement and remove.
- o Can be used in water application where culvert is ice free.

(d) Disadvantages

- o Will not prevent oil from migrating if water is flowing fast.
- o May be difficult to establish a seal between barrier and front of culvert.
- o May be difficult to suspend the barrier above the culvert bottom.
- o Ice formation may hamper winter construction and use.

3.8 ICE SLOTTING

Containment and recovery of oil from under ice can pose numerous problems.

Often it is difficult to determine where oil is located and, if it is moving, the majority of oils will float on the surface and collect between the ice and water level.

Punching holes through the ice is a good way to determine location of the oil. Slotting ice can be an effective method to contain oil movement in slow moving bodies of water. Techniques of ice slotting should be reviewed by reading the Oil Spill Containment and Recovery Technical Manual.

4. OIL SPILL RECOVERY

4.1 OVERVIEW

Fluids contained within the spill area must be recovered and disposed of in a way that is acceptable to the concerned parties. In some situations, this may also include water which has entered the recovery area along with the product. It is critical to remove as much oil as possible, so that final cleanup and restoration procedures are both environmentally acceptable and cost effective.

4.2 FLUSHING

(a) Application

Flushing with fresh water can be an effective method for enhancing the oil recovery process and reducing the amount of residual oil left in the muskeg. By flushing with either warm or cold water, the oil is herded to a central collection point where the fluid can be selectively removed by skimming and pumping. The herding process can be carried out using the feeder trench system or on the surface of the water as shown in Figure 17.

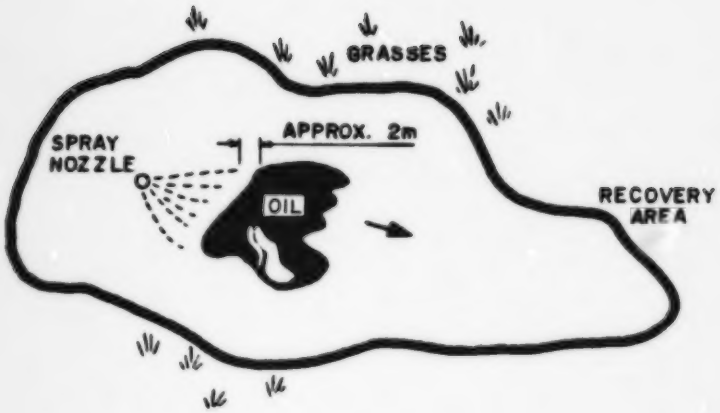

FIGURE 17. OIL HERDING ON OPEN WATER

(b) Limitations

Flushing can have limited application in muskeg with low water tables because the oil is often deeply soaked into the organic mat. Excessive water volumes may prevent the oil from surfacing, therefore reducing the efficiency of the flush. However, care must be taken during winter spills so that the warm water does not drive the oil deeper into the soil by melting the frost layers. The water should not be so hot that it will kill vegetation.

(c) Advantages

- Can be used in areas with open water or extensive vegetation.

- o Low pressure sprays remove oil from vegetation without excessive damage to the plants.

- o Can be used in summer and some winter cleanup operations.

(d) Disadvantages

- o Mixing and emulsification of the oil may occur if the nozzle is sprayed directly at the oil slick.

- o High pressures may drive oil deeper into organic layers.

- o High pressures may damage vegetation.

- o Additional equipment (ie. hot oiler units) may be required to generate warm water.

4.3 FLUID RECOVERY

Once the fluid has been contained and directed to a recovery area, a decision should be made whether to recover the total volume of fluid or to remove the surface oil by mechanical skimming or sorbents. In cases where heavy oil has spilled, the product may sink to the bottom, in which case surface water may have to be removed prior to recovering the oil.

(a) Application

In cases where total volumes must be recovered, equipment such as pumps, tank trucks, vacuum trucks and super suckers can be used.

When the oil is to be skimmed from the surface, various types of mechanical skimmers are available. When small spills exist, materials such as sorbents are effective.

(b) Limitations

Pumping and skimming equipment must always be used in a safe atmosphere to prevent fire or explosion. In many cases this concern will limit the type of skimming unit which can be used for recovery.

Sorbents have limited application in large spills and are most effective when used during final cleanup.

TABLE 3. Advantages and Disadvantages of Recovery Equipment

EQUIPMENT TYPES	ADVANTAGES	DISADVANTAGES
Tank trucks Vacuum trucks Super Suckers	o readily available in most areas o mobile o some units are equipped with floatation tires for easier access o handle large volumes	o access to spill sites may cause extensive damage o may require assistance to enter an area during wet conditions o expensive o may require trash screens on suction line o may form emulsions during pumping and tranfer phases of recovery o keep back from hazardous areas
Pumps	o portable o can be used to transfer fluids long distance if heavy equipment cannot access spill site	o may cause fires or explosions o require maintenance checks o transfer lines or hoses should be staked to prevent movement while under pressure
Suction Skimmers	o readily available and portable o inexpensive o simple to operate o good on land or stagnant water where oil layer is thick o can handle a variety of oils	o requires additional equipment such as a pump or vacuum truck for fluid transfer o limited to land or stagnant water recovery o requires supervision o ratio of oil to water recovery can be poor o may become plugged with debris o fluid transfer units may not function properly if air is introduced into the line o limited in heavy oils o may have to be moved from oil oil pool to another
Weir Skimmers	o most types can be operated manually or automatically o more efficient than suction skimmers o some types work well in both stagnant and moving water conditions o simple to operate o relatively inexpensive o readily available o units are safe, however, transfer units should be kept away from the spilled material o some are designed for cold weather usage weather usage	o requires additional equipment such as a pump or vacuum truck o limited to light and medium oils o can be hampered by surface movement (ie. waves) o can be plugged with debris o oil should be directed to the skimmer lead

TABLE 3. Continued. Advantages and Disadvantages of Recovery Equipment

EQUIPMENT TYPES	ADVANTAGES	DISADVANTAGES
Disc Skimmers	o excellent oil/water recovery ratio o can operate in shallow conditions o easy to handle o work well in stagnant conditions o can be used for subsurface recovery o cost effective o good for most light to medium oils o disc and pump rates can be controlled from shore o can be used to skim oil from surface storage tanks	o expensive o mechanically complex o wave action limits recovery o sensitive to trash collection around discs (fibres around shaft) o limited to slow current o limited in heavy oil
Sorbents	o are available for recovery of many oil types o high oil to water recovery rate o some brands can be reused o best used in final cleanup as opposed to initial recovery o does not require the use of heavy equipment	o can be labour intensive o must be disposed of in an environmentally acceptable manner o limited to stagnant water o weathered oil may be difficult to recover

For more information on the various types of recovery equipment and their uses, please refer to "Oil Spill Technical Manual for Inland Spills".

5. OIL SPILL CLEANUP

One of the major cleanup problems in muskeg areas is that oil becomes trapped in voids, or between organic layers, and can be difficult to remove and recover. This is particularly true in low water table areas or during low precipitation periods. At this stage of the cleanup, it may be necessary to employ additional methods such as stripping, burning and manual removal.

5.1 STRIPPING

(a) Application

Stripping oil-soaked muskeg into windrows may aid oil collection and natural decomposition because the oil will drain from the windrow more readily (by gravity), any remaining oil will degrade faster because of increased exposure to air. The windrows or piles of oil-soaked muskeg, also burn more easily, thus damage from burning is localized.

(b) Limitations

Stripping procedures should be carried out during frozen ground conditions, or if the water table is extremely low. At these times of the year damage to the surrounding soil layer will be reduced. Every effort should be made to strip only the oil-soaked portion and avoid adding clean peat or soil to the pile as this increases the amount of material which must be reclaimed.

Stripping procedures should not be carried out when the water table is high as the area between windrows may be under water, thus complicating future access and reclamation procedures.

5.2 BURNING

Burning oil in a muskeg spill can be an effective method of reducing the volume of oil. This alternative should be considered when the product is highly volatile and the area is unsafe for cleanup crews, and when the use of heavy equipment for containment and cleanup will create significant environmental damage.

The decision to burn should be made as soon as possible to utilize the presence of light ends in the product. Weathered oils can be extremely hard to ignite.

When done properly, burning can produce good results.

All the necessary approvals from government, as well as safe ignition procedures must be used by cleanup personnel when burning a spill.

(a) Application

The most suitable circumstances for burning are new oil spills which occur in winter or in muskeg with a high water table. Burning in containment trenches is often effective, as the burn is localized and continues as oil collects in the trench. Oil migration and collection can be increased by burning as the heavier hydrocarbons are heated and flow more readily.

(b) Limitations

The situations which present the most concern when burning are:

- o Weathered spill sites.
- o Areas which have vegetation cover that has not been damaged by the spill.
- o Areas where the organic cover has been deeply penetrated by the oil. Burning weathered spill sites may be difficult as most or all of the light ends have evaporated. Products such as diesel fuel and gasoline are used to initiate the burn, however, these fluids may lead to further contamination.

Burning in muskeg where the water table is low may destroy root systems, thus reducing the potential for natural revegetation. Depending on the product type, a tarry residue often remains after the burn which can seriously impede plant growth because of alterations in normal aeration, soil moisture and plant nutrients.

To prevent the spreading of fire, burns should only be carried out on areas where the fire can be contained. In some cases, a fire break may have to be constructed to prevent additional fires. Burns which are initiated may result in smoldering muskeg, possibly igniting at a later time. Forestry personnel can assist in determining whether or not any of these concerns exist.

Winter burning may cause thawing and increase the potential for oil penetration. Spill areas must be contained so that water formed as the snow melts remains on site.

5.3 MANUAL REMOVAL

In small spills, it may be possible to clean much of the area by manual methods. Although labour intensive, manual techniques result in satisfatory cleanup and reduce reclamation costs In some cases, spilled fluids can be squeezed from the organic layers and be directed to recovery trenches using special equipment (e.g. squeegy, hand rollers). In other cases, vegetation which protrudes above the water surface can be cut (5-10 cm) below the water line and the material removed for disposal. In most cases, the plant will return the next year if the root system has not been damaged. Sorbent pads, blankets and sweeps can be used to remove contamination in small areas.

(a) Application

This method is most effective in small spills and in areas where equipment of any type will create surface damage.

(b) Limitations

Water depth, presence of vegetation and stability of sub-surface soils will dictate whether or not this method is viable. Cleanup personnel must not be allowed to enter an area until a check is made for explosive vapours of H_2S and is otherwise safe.

5.4 DISPOSAL OF OILY DEBRIS

Oil spills on land or water may produce significant volumes of liquid and solid wastes which must be stored on site and then disposed of in an environmentally-acceptable manner. In some cases this material must be transported from the storage area to the final disposal site. During these operations proper storage, transportation and disposal procedures must be used.

The disposal process is generally the final step in most cleanup operations, although site reclamation may be necessary. Disposal requirements depend on the spill size and location, product type, recovery techniques used, waste characteristics, environmental factors and public concerns.

Table 4 summarizes methods that can be used to store oily debris until it can be diposed. Table 5 lists the factors to consider in selecting the best method(s) of disposal.

For more information on these subjects, please refer to the "Oil Spill Technical Manual for Inland Spills".

TABLE 4 STORAGE OF OIL SPILL DEBRIS

CONTAINER TYPES	FLUID MATERIALS	SOLID MATERIALS BURNABLE	SOLID MATERIALS NON-BURNABLE	CONTAMINATED SNOW AND ICE
Portable Tanks	Excellent	Limited to small debris	Limited	Limited to small quantities
Skid-Mounted Tanks (Rig Tanks)	Excellent	Excellent	Excellent	Excellent
Upright Tanks (200-400 bbl) 32.7 m^3-65.4 m^3	Limited	Poor	Poor	Poor
Pillow Tanks Bladder Bags	Limited	Poor	Poor	Poor
Barrels Drums	Excellent (limits to quantity)	Limited	Limited	Poor
Tanks and Vacuum Trucks	Limited (not cost effective)	Poor	Poor	Poor
Earthen Pits (lined if necessary)	Limited to proper construction	Excellent	Excellent	Excellent
Garbage Bags	Poor	Limited small debris	Limited	Poor

TABLE 5. Disposal of Oil Spill Debris

METHOD	ADVANTAGES	DISADVANTAGES
Pipeline Reinjection	o close to source o can be used for both oil and water o simple implementation o unlimited volumes o cost effective compared to trucking	o cannot be used for solids o requires filtration and possible chemical addition o can be expensive if filtration is needed o requires pressure units
Deep Well Injection	o safe disposal method o cost effective o simple implementation	o suited for fluids only o sites are limited and may require long transportation hauls o fluids must be clean o must be compatable with other fluids and formations o chemical addition for corrosion control may be required
Reprocess	o oil is salvaged o cleanup cost is reduced by selling oil o method is safe	o facility must be close to spill o facility may not handle fluids as fast as required o transportation costs may exceed recovered oil's value o may have to pay for cleanup o fluid storage is limited o may not be able to separate debris and emulsions
Recycling	o oil is reused o disposal method is safe o cost is effective	o restricted to oil disposal o oil must meet certain criteria o facility may be a long distance away o may not be able to separate debris and emulsions o may require specific equipment for disposal
Surface Release	o cost effective o safe o close to source o simple implementation	o restricted to water disposal o may require long retention periods o may require outside heat source o hampered in winter o requires government approval
Road Oiling	o oil is used o cost is effective o dust control	o oil must meet certain criteria o special application precautions o requires monitoring o requires government approval o requires use of heavy equipment

TABLE 5. continued. Debris Disposal Methods

METHOD	ADVANTAGES	DISADVANTAGES
In-Situ Burning on Water	o cleanup and disposal in one operation (fast) o cost effective o eliminates need for much equipment and workforce in hazardous areas o useful in remote areas	o restricted to oil o fire hazard o creates black smoke o tarry residues may form o limited in winter o may require fire fighting equipment to be on hand o may require wicking agents and igniters
In-Situ Burning on Land	o cleanup and disposal in one operation (fast) o cost effective o destroys oils and debris o eliminates need for some equipment and workforce o easy to implement o reduces safety hazards for workforce o useful in remote areas o disposes of large oil quantities	o fire hazards o creates black smoke o tarry residues may form, requiring additional treatment o may need to use burning promoters o may destroy plant, animal and soil life o limited in winter o may require fire fighting equipment to be on hand
Open Pit Burning	o destruction is fast and permanent o reduces transportation needs o useful in remote areas o no long-term monitoring o fire hazard less than in-situ burning o very cost effective	o must dispose of ash o restricted to oily debris o air emissions o black smoke generated o temperatures uncontrolled o requires permits o requires equipment to construct pit o requires safe handling procedures o should not be used for sand and gravel
Incinerators	o can burn oil emulsions and most debris o useful in all areas o safe o destruction process is fast and permanent o no long-term monitoring o black smoke is eliminated o temperatures can be controlled o fire hazards minimal o portable for remote areas	o may be hard to obtain units o multiple units may be needed o requires heavy equipment for set-up

TABLE 5. continued. Debris Disposal Methods

METHOD	ADVANTAGES	DISADVANTAGES
Biodegradation Natural In-Situ Enhanced In-Situ Remote	o long term effects minimal o cost effective o requires minimal workforce o safe, proven method	o restricted to oil contaminated with oil o requires specialized equipment and precautions o requires long term monitoring o requires soil and waste monitoring o requires addition of soil amendments and regular maintenance o may take many years for biodegradation o may require transportation of material (in remote cases) to disposal site o restricted to summer months for biodegradation o water saturated soils are harder to degrade
Sanitary Landfills and Excavated Pits	o fast and cost effective	o materials can resurface o possible ground water contamination o transporting debris to site may be expensive o restricted to dry solid debris o requires heavy equipment for excavation o requires extensive site monitoring in its natural state o oil remains for a long period of time

6. SALT WATER SPILL CONTAINMENT

6.1 INTRODUCTION

Salt water, or brine, spills are becoming more frequent in forested areas and it is expected that they will increase in number and size as existing pipelines increase in age. Brine spreads horizontally and vertically in muskeg more then does oil. It mixes with water and being heavier then fresh water tends to mix quickly. A rapid response and recovery is essential in order to control the size of the contaminated area. Depending on the site conditions, reclamation measures may be long term and costly unless mitigative actions are taken during cleanup.

Initial requirements for sampling, assessing, and documenting salt water spills have been addressed in Section 2. Brine spill initial assessment and monitoring during recovery and cleanup in muskeg requires specific measures different from those used to response to an oil spill.

It is difficult to determine the three dimensional size of a brine spill in muskeg because it is not visible, more dense and mixes with fresh water. Determining the initial size of the affected area requires taking samples and field or laboratory analysis. The information is needed for determining spill containment and recovery strategy.

6.2 CONTAINMENT TECHNIQUES

6.2.1 Earth Dikes

Construction methods for dikes is described in Section 3.3.

(a) Application

Dikes can be used effectively to contain brine spills in muskeg. They may serve three purposes:

(1) A dike may be used to contain the contaminated area so that removal operations can begin immediately (if a brine spill in muskeg is identified soon after its occurrence),

(2) A dike can be used to restrict flow from the muskeg into adjacent surface water bodies, or

(3) Dike construction allows workers and equipment into the spill affected area to install and operate recovery equipment.

(b) Limitations

There are three limitations to using dikes as a containment method:

(1) There will be damage to the land area used as the clay borrow source,

(2) Cut and fill operations may be required from the borrow source to the spill site for roads and pads, (Reclamation of these areas is required following brine removal.) or

(3) It may be necessary to remove portions of the dike or open drainage channels through the dike as part of site rehabilitation.

(c) Advantages

- o Provides spill containment
- o Provides working platform

(d) Disadvantages

- o Creates major disturbances
- o Requires heavy equipment
- o Will increase reclamation costs

6.2.2 Trenches and Bellholes

(a) Application

The bell hole (sump) and trench construction in muskeg can be an effective initial step in brine recovery. Bell holes provide suitable open water locations for installing pumps for brine removal. Trenches radiating out from the bell holes may be added to provide pathways for the brine to flow toward the bell hole caused by the

reduced water level created by pumping. The number, dimensions and locations of bell holes and trenches needed will be site specific and can be best determined during the initial spill site assessment. Combined with flushing, this can be a very effective means of recovering the salt water, and is usually the preferred method.

In most cases, the initial trench should be excavated through the centre of the spill to provide access to the highest salt concentrations. Additional trenches may be excavated in a herringbone pattern from this central trench or radially from the bell hole(s). Bell holes should be situated at one or more locations along the centre trench. Additional bell holes may be required depending on spill size.

Pumping from the bell holes should begin as soon as they are in place. Brine recovered should be pumped to a water truck or other temporary storage vessel for subsequent removal and disposal or pumped directly into the repaired pipeline or temporary surface line to minimize cost.

Bell hole and trench excavation may be advantageous for containment and removal in a specific spill site, as costs are much less than for dike construction. As well, reclamation measures are usually less expensive.

(b) Limitations

Depending on the muskeg type and the surrounding terrain, it may not be possible to gain access without causing considerable disturbance. Depending on the area affected, the spill source location, and the muskeg type, equipment access may not be possible. In such cases, bell holes should be excavated manually before pump

installation. These factors should be addressed during initial site assessment.

Section 3.2 describes construction methods for trenches and bellholes.

(c) Advantages

- o Spill diversion and containment.
- o Used to lower water level and recover spilled fluids.
- o Enhances spill site drainage and facilitates flushing.

(d) Disadvantages

- o Requires access by Nodwell mounted backhoe or equivalent.
- o Large volumes of water to be disposed of.

7. SALT WATER SPILL RECOVERY

Prompt action by knowledgeable field personnel will be necessary to maximize brine recovery after a salt spill in muskeg. Lateral and vertical migration can be much faster than that of oil. Rapid recovery will minimize the spill contaminated area reducing cleanup and reclamation cost. The faster the spill recovery, the lower the risk of tree loss and loss of ground cover. A prompt spill response and recovery also means less contaminated water for disposal.

7.1 RECOVERY TECHNIQUES

7.1.1 Bell holes

(a) Application

Brine recovery can be inititated quickly by installing one or more bell holes alone or in conjunction with drainage trenches close to the centre of the spill.

The principal of pumping brine from bell holes is to reduce the water level at that location. This creates a shallow cone of depression, depending on the pumping rate. The cone of depression will induce the inflow of water as shown in Figure 18.

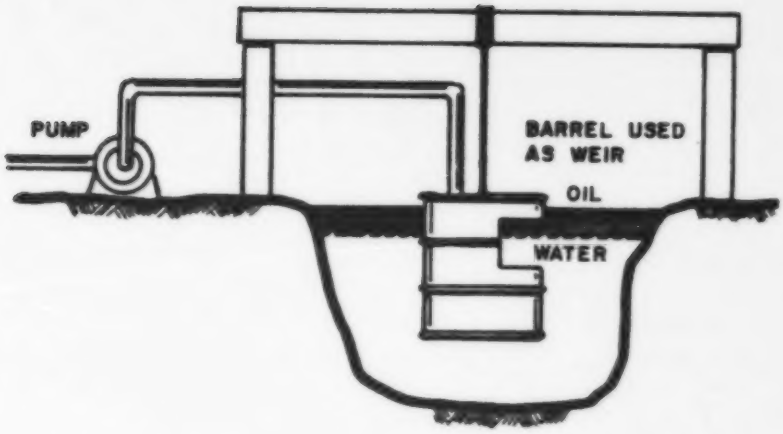

FIGURE 18 CONE OF DEPRESSION AROUND BELL HOLE

Brine recovery from a muskeg is often a long term operation. The influx of organic debris may clog pump intakes. To minimize pumping problems and maximize recovery, it may be desirable to insert a slotted, galvanized steel culvert into the borehole to serve as a coarse filter and sump. A culvert diameter of about 1 m is recommended. Slots can be cut in the field using a cutting torch. About 10 per cent of the culvert surface below the water should be slotted. The perforated walls will allow for free flow of more dense salt water into the bell holes, thus speeding recovery.

(b) Limitations

Reducing the water level in the bell hole and the effective radius of the cone of depression created by pumping from a bell hole depends on:

- o the pumping rate. (This can be controlled by culvert size, adding drainage trenches and pump capacity.)

- o the water inflow rate, which is a function of permeability of the muskeg and is site specific.

If the permeability rate of the muskeg becomes the limiting factor to pumping rate, trenches radiating outward from the bell hole can be excavated to speed the inflow of water.

(c) Advantages

- o Effective way of recovering brine.

- o Lower water table creating inward flow and natural flushing.

- o Reduces lateral migration.

(d) Disadvantages

- o May encounter low flow conditions.

- o High concentration of salts in bell holes after fluid recovery, flushing required.

7.1.2 Flushing and Pumping

(a) Application

It is possible to move brine from the muskeg into trenches and bell holes by fresh water flushing. The flushed brine

is pumped from the bell holes for temporary storage or disposal. The fresh water sources may be a nearby surface water body with water transported by pumps and hoses or water trucks. The choice of method will depend on distance and road access to the site.

After installation of the pumping system, flushing can be started from the outer boundary of the spill site. Flushing rates should be slow. Fresh water can be applied under constant pressure through perforated pipe or hoses from a header off the water truck or from a pump.

Monitoring chloride concentrations or electrical conductivity of the pumped water will be required during the ongoing recovery operation. Monitoring salt concentrations inside the flushed area also may be required. If these salt concentrations decline significantly, the flushing operations should be moved toward the bell hole.

Pumping operations should be discontinued when a chloride concentration of 500 ppm has been reached and maintained for several days. Further monitoring is recommended after pumping is stopped as it is common for salt concentrations to increase over time as salts bound by soil and organic material are released into solution. Monitoring and additional pumping should be continued until the chloride concentration stabilizies at a level of 500 ppm or less.

(b) Limitations

Flushing and pumping a salt water spill results in large volumes of water for disposal. The water will have relatively low concentrations of salt and will usually be trucked or pumped to a disposal well. The capability of the disposal well to handle these additional volumes should be evaluated. To avoid the costs of

trucking, installation of a temporary flow line or connection to existing disposal lines should be considered. Corrosion inhibitors, biocides or other treatment of the disposal water may be needed before injection.

(c) Advantages

- o Increases total salt recovered.
- o Dilutes salt concentration thereby protecting vegetation.
- o Very effective in moving salt water into trenches and bell holes.

(d) Disadvantages

- o Increases total volume of waste water for disposal.
- o May be labour intensive.
- o Can only be done when temperature is above freezing.

8. SALT WATER SPILL CLEAN-UP

8.1 TEMPORARY STORAGE

Temporary storage for recovered brine will be necessary in the early stages of pumping before pipeline repair and brine reinjection. This may be done using portable storage tanks or slop tanks at the site.

If suitable site conditions exist, a temporary storage pit may be constructed by excavation, followed by installation of a suitable clay and/or a synthetic liner. Brine pumped from the muskeg can be placed in the storage pit to allow solids to settle, and to remove floating organic debris by skimming.

8.2 TRANSPORTATION

In preliminary recovery stages it may be necessary to transport brine by water trucks if site access conditions will permit it. If a temporary holding pond is used, a boom could be used to remove vegetation and other floating cleanup debris. There would be sufficient time for solids to settle.

If the spill's cause was a pipeline failure, then repairs should be initiated as quickly as possible so that brine can be reinjected into the line, reducing storage and transportation costs. Reinjecting the recovered brine directly into the pipeline may not be possible because of debris or corrosion concerns. The recovered brine will probably require:

- o Cleaning to remove sediment.

- o Treatment when inhibitors and biocides before reinjection into the formation.

This should be checked with the field operations staff before implementing. A temporary surface line with rig pumps is a possible alternative.

8.3 DISPOSAL

The only suitable means for brine disposal is injection by deep well disposal. If injection wells are not close to the spill site a suitable means of transport must be arranged.

9 RECLAMATION

9.1 PLANNING

Reclamation planning should start early in spill cleanup. These plans will most probably change as cleanup progresses and more is learned about the site and the extent of damage. It is important to keep reclamation in mind during the cleanup and in so doing, avoid practices which might seriously complicate or jeopardize final site restoration.

9.2 SITE CONSIDERATIONS

Reclamation in a muskeg area could differ from that at an upland site because:

- The wet (often saturated) and cool condition of peat soils.
- The shorter and cooler growing season.
- The differing plant community in the peat (dominantly aquatic or non-vascular plants, e.g. moss).
- The differing soil chemistry of the peat (i.e. often acidic, possibly saline and generally nutrient poor).

Because of these factors, muskeg reclamation (back to original conditions) generally requires a longer period of time than does upland spill sites. Coupled with this is the soft condition of the peat which can result in considerable physical disturbance during cleanup. Access may create restrictions in implementing the

necessary reclamation measures. Because of this access problem, it is often necessary to add soil amendments and other aspects of the reclamation when the ground is frozen or from the air by helicopter.

Some reclamation measures which may be required but are not necessarily unique to muskeg are:

- o Fertilizer application (primarily nitrogen and phosphorous).
- o Addition of lime to reduce acidity and stimulate plant regrowth and oil decomposition.
- o Tillage to break up a surface crust (particularly if burned) and promote aeration and seed germination.
- o Improvement for drainage patterns within the muskeg.
- o Reseeding or planting to hasten re-establishment of plant cover.

More detailed information on reclamation procedures for muskeg areas is available in other publications and from research, government and industry personnel who have been directly involved in such work. There is no common cookbook or uniform set of reclamation procedures which apply to all muskegs. This is because of the varying conditions and the unique circumstances related to each spill. It is important to consult directly with those people who have first-hand working experience and professional reclamation training.